Spin Dynamics of Na Guest in Type II Si Clathrate

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We report the temperature dependence of relaxation time (T_1) and phase memory (T_M) of Na dopants in type II Si clathrate films utilizing electron paramagnetic resonance (EPR). Type II silicon clathrates represent an interesting alternative crystal structure to the more commonly studied diamond silicon. This cage-like inclusion compound is made up of a silicon lattice with interstitial "guests" such as sodium. The guest atoms, which are decoupled from the lattice, act as shallow donor atoms and are potential qubits. Our recent advances have allowed the synthesis of Na guest, type II Si clathrate films with low enough Na concentration for the Na to be considered a dopant and the spin dynamics of isolated Na donors to be investigated.

EPR gives insight into the electronic properties of the Na donors and their placement and interactions within the silicon cages. The naturally occurring Na isotope, ^{23}Na, has nuclear spin 3/2 with the EPR spectrum exhibiting four hyperfine lines associated with the interaction of the electronic and nuclear spins. Pulsed-EPR spectra clearly exhibit spin echo signals. Probing the spin echo decay of the hyperfine lines corresponding to isolated Na guests reveals T_1 times in the hundreds of microseconds and T_M times above a microsecond at temperatures near 7 K. The temperature dependence of spin-echo signals provides insights into the mechanisms of electron spin relaxation and loss of phase memory in this system.The effects of various parameters (i.e. temperature, pulse duration, magnetic field center) on the relaxation time and phase memory are also explored. Results of this work provide new understanding of the spin dynamics of Na in type II Si clathrates and provides useful insights into the potential use of Na in type II Si clathrate as a qubit material. This work was supported by National Science Foundation award #2114569.